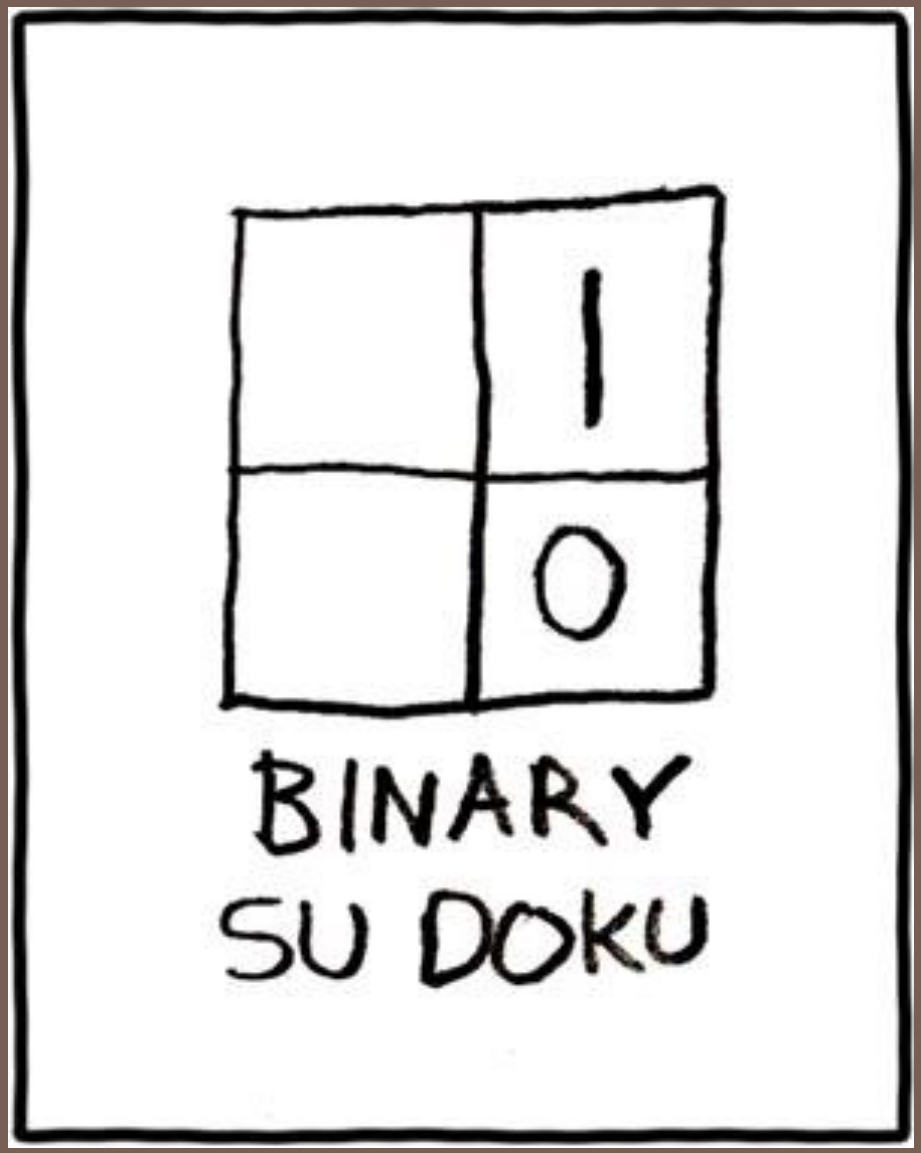
IMPROVING THE ENERGY EFFICIENCY & ENVIRONMENTAL PERFORMANCE OF GOODS MOVEMENT



James J. Winebrake, PhD., Rochester Institute of Technology

Asllomar 2009 Conference on Transportation and Energy

Working Hypothesis

- We can solve a large part of the energy and environmental problems of freight transportation by moving goods off trucks and onto trains and ships.

V.

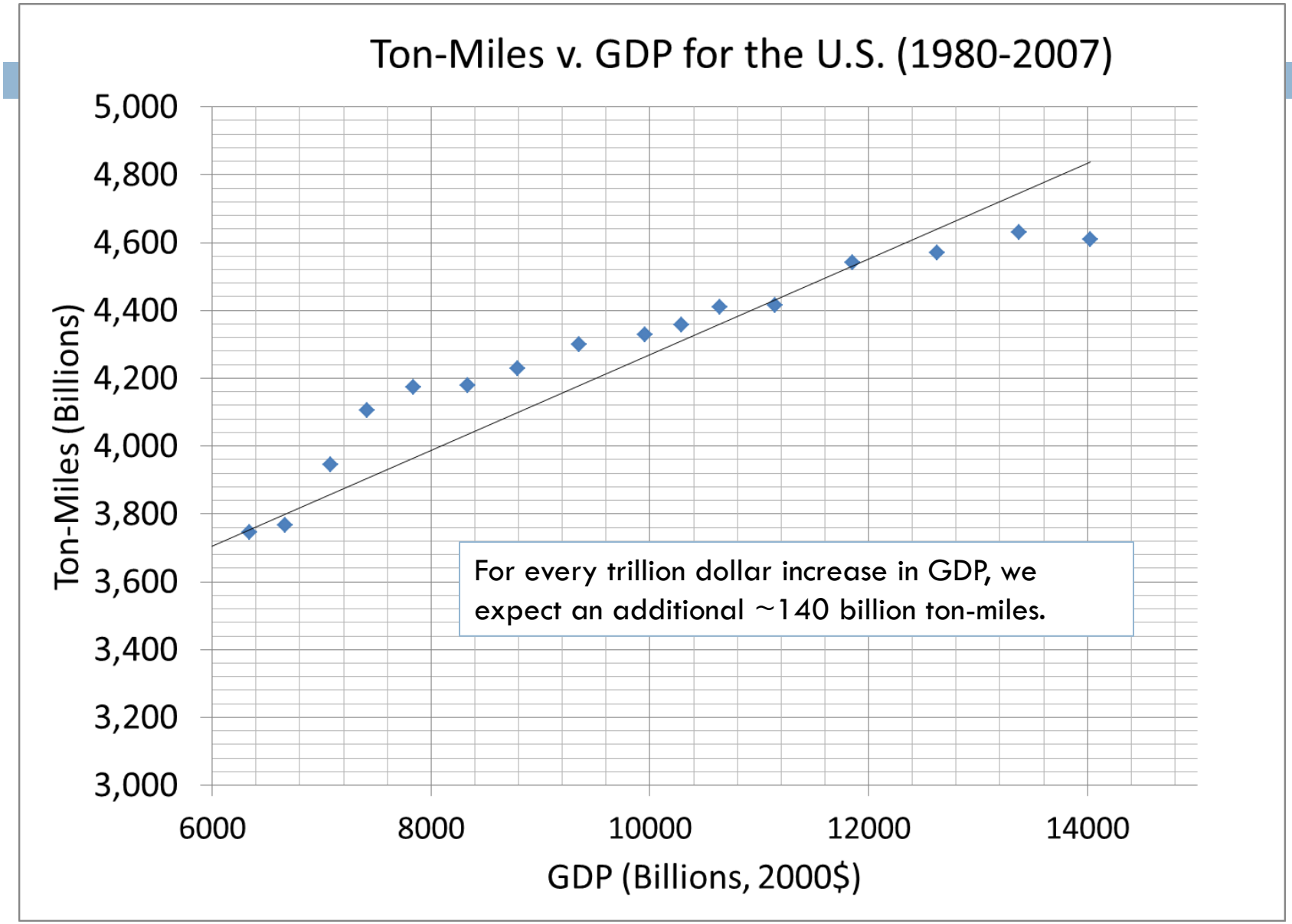
J. Winebrake, Asilomar, 2009.

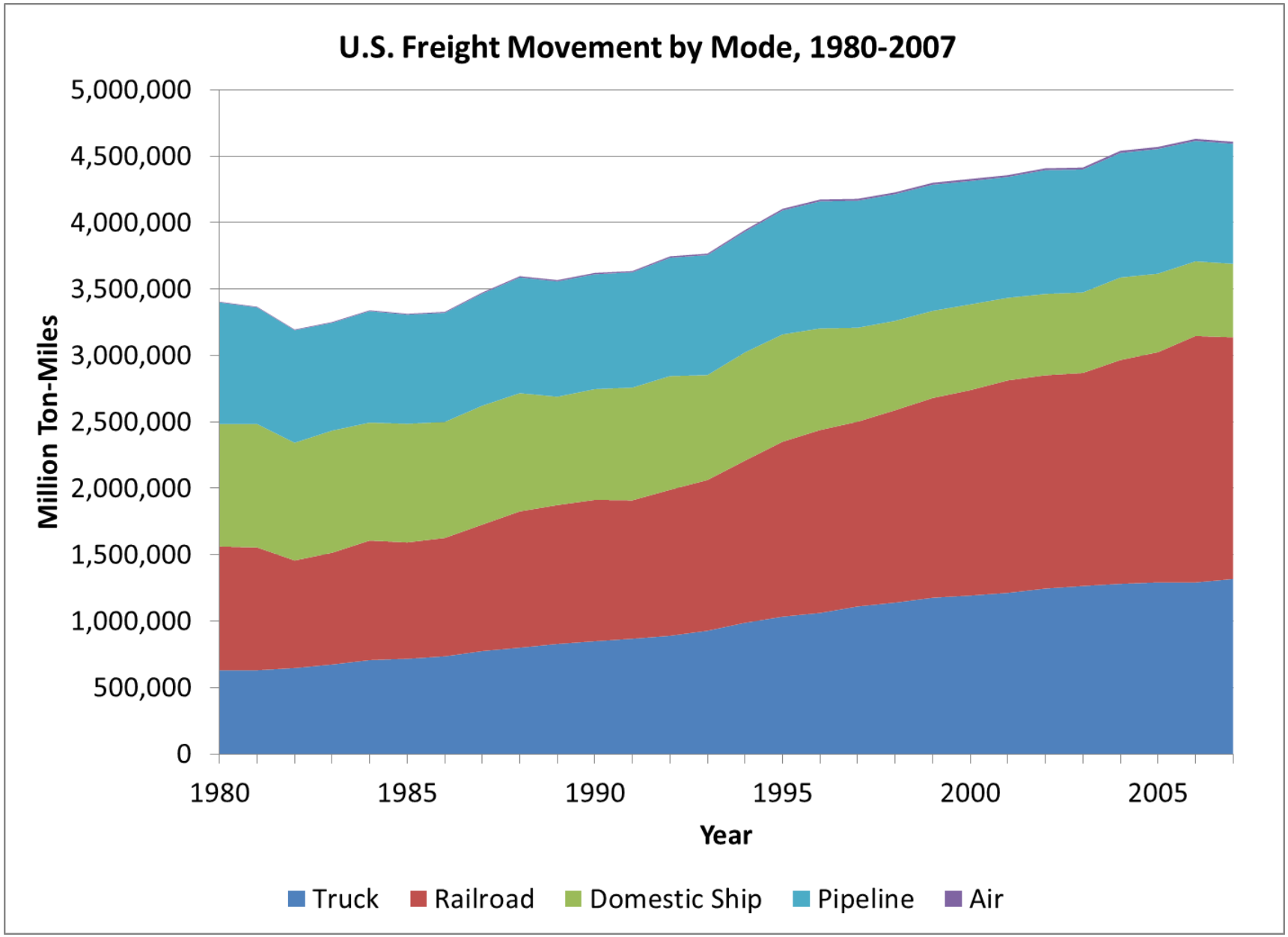
Overview of Goods Movement

J. Winebrake, Asilomar, 2009.

Freight Transport and Modal Comparisons

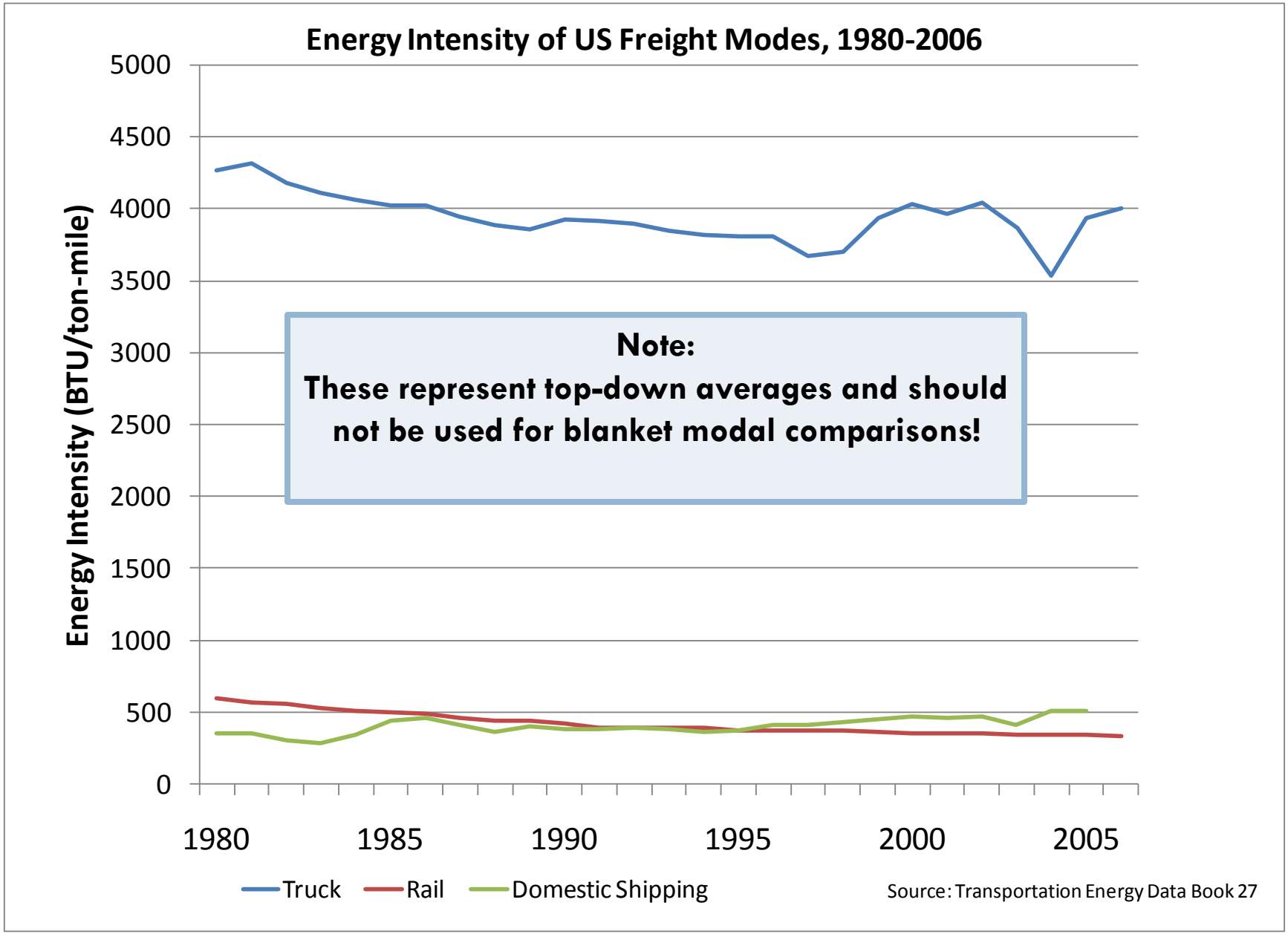
Goods Movement and GDP



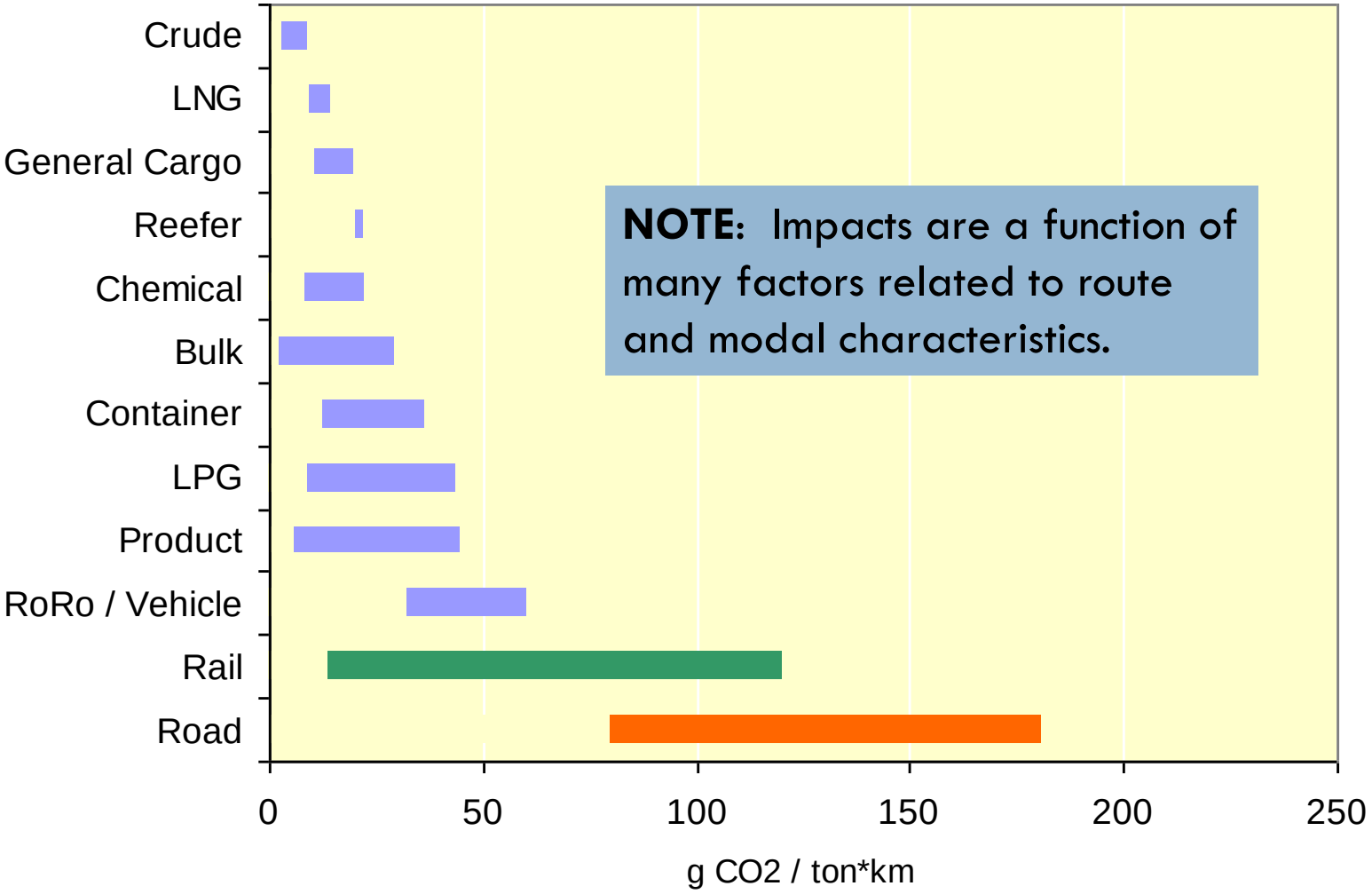


J. Winebrake (2012)

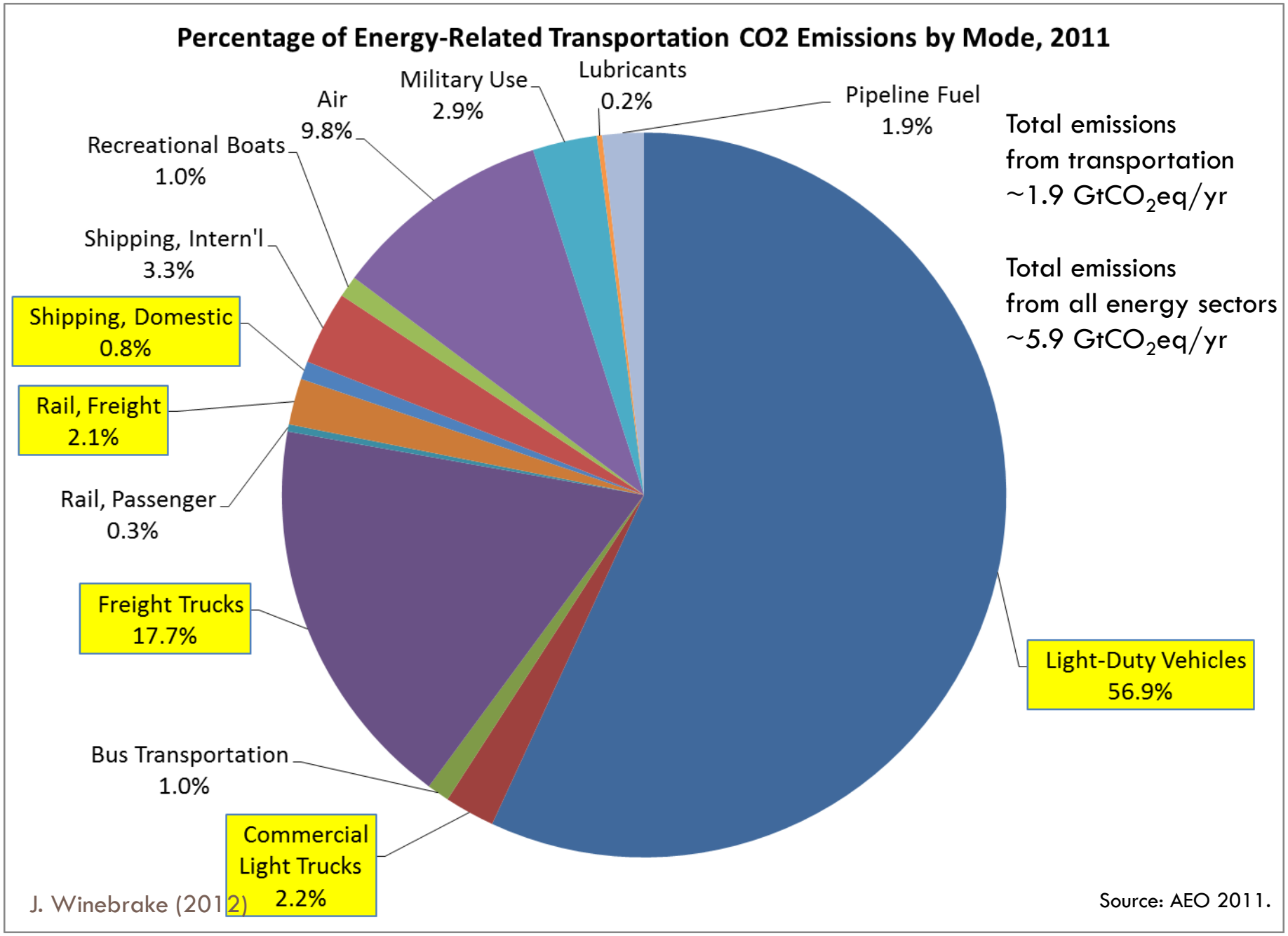
Source: BTS (2011)

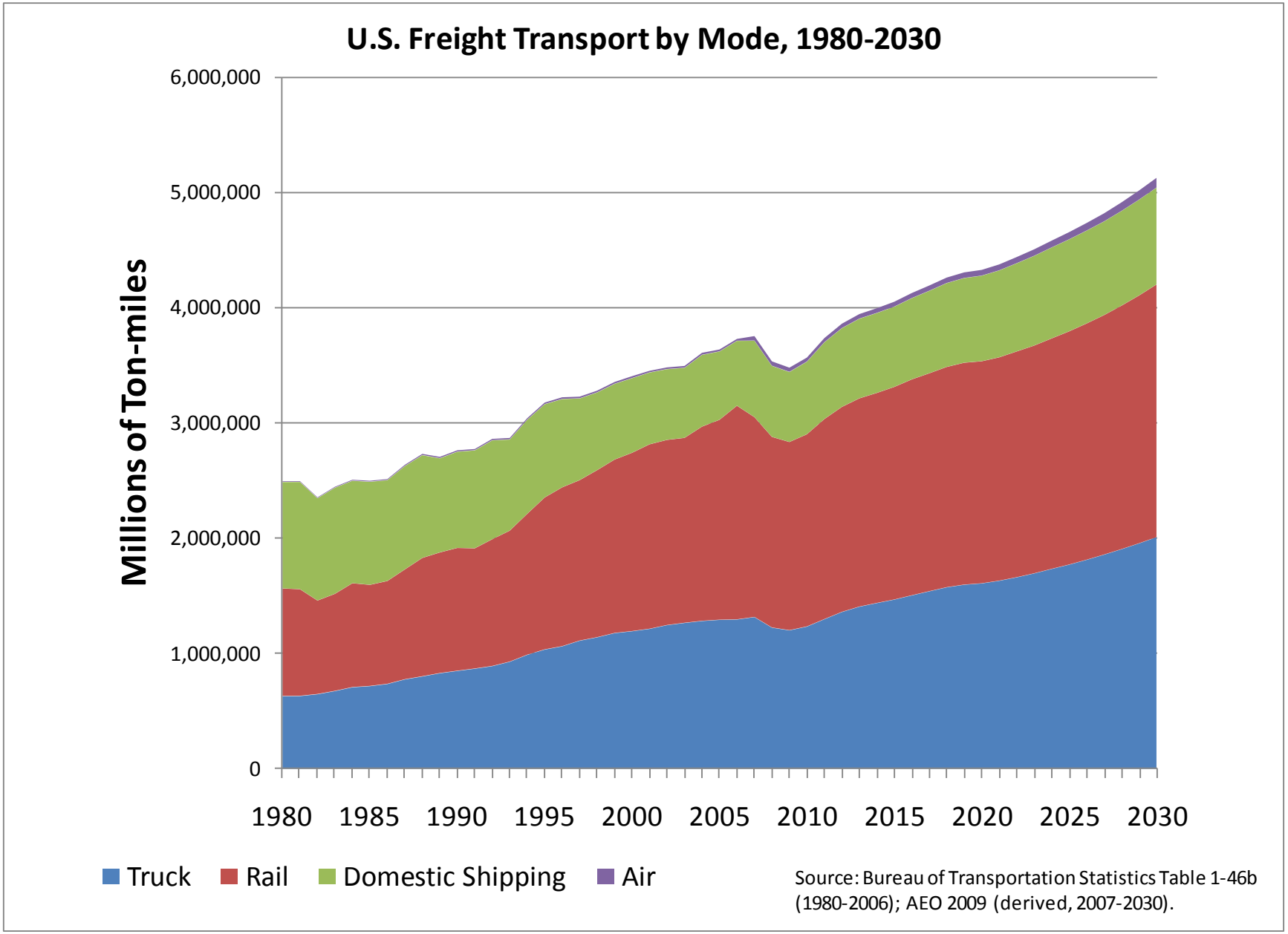

Energy Intensity of US Freight Modes, 1980-2006
Energy Intensity (BTU/ton-mile)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
Note:
These represent top-down averages and should not be used for blanket modal comparisons!
Truck
Rail
Domestic Shipping
Source: Transportation Energy Data Book 27

Range of typical CO2 efficiencies for various cargo carriers



Source: Buhaug, et al. 2009


Percentage of Energy-Related Transportation CO2 Emissions by Mode, 2011
Military Use 2.9%
Lubricants 0.2%
Pipeline Fuel 1.9%
Air 9.8%
Recreational Boats 1.0%
Shipping, Intern'l 3.3%
Shipping, Domestic 0.8%
Rail, Freight 2.1%
Rail, Passenger 0.3%
Freight Trucks 17.7%
Bus Transportation 1.0%
Commercial Light Trucks 2.2%
Light-Duty Vehicles 56.9%
Total emissions from transportation ~1.9 GtCO2eq/yr
Total emissions from all energy sectors ~5.9 GtCO2eq/yr
J. Winebrake (2012)
Source: AEO 2011.



J. Winebrake, Asilomar, 2009.

Oh, and if you believe these slides ..

These are all "Wrong"

… or they are right, but only for limited decisions facing the freight sector

… and they may not address the question of greatest importance: How will freight innovation serve 21st Century goals?

J. Winebrake, Asilomar, 2009.

Numerous Impacts of Goods Movement

(JJW this is where we say, community is only beginning to address freight innovation needs)

- Noise and vibration
- Land use compatibility/zoning
- Local traffic impacts
- Socio-economic characteristics of the community
  - Environmental justice
  - Community impacts
- **Air pollutant emissions (including greenhouse gases and PM emissions)**
- Water quality
- Energy consumption
- Hazardous waste contamination
- Natural resources
  - Wildlife habitat
  - Vegetation
- Cultural resources
  - Historic structures
  - Archaeological sites
  - Landscapes and traditional cultural properties

Overview panelists areas of focus?

- Names, and short intro for each.

Taxonomy of model goals/needs?

IFTOLD context may be useful

- I
- F
- T
- O
- L
- D

Perspective based overview

- Fed Infrastructure planners
- State/Regional MPOs
- Energy providers
- Terminals, corridors
- Fleets, facilities
- Beneficial cargo owners/shippers

J. Winebrake, Asilomar, 2009.

Opportunities for Mode Shifting

Example of the kind of issue modeling may pursue – or may fail to pursue, in favor of other ideas.

J. Winebrake, Asilomar, 2009.

The IF-TOLD Mitigation Framework: A Context for Mode Shifting Discussions

- The IF-TOLD "six-legged cow":
  - ***I***ntermodalism/mode-shifting – use of efficient modes
  - ***F***uels – use of low carbon fuels
  - ***T***echnology – application of efficient technologies
  - ***O***perations – best practices in operator behavior
  - ***L***ogistics – improve supply chain management
  - ***D***emand – reduce how much STUFF we consume

Even a six-legged cow can move all legs – dynamic, balancing!

J. Winebrake, Asilomar, 2009.

Opportunities for Mode-Shifting

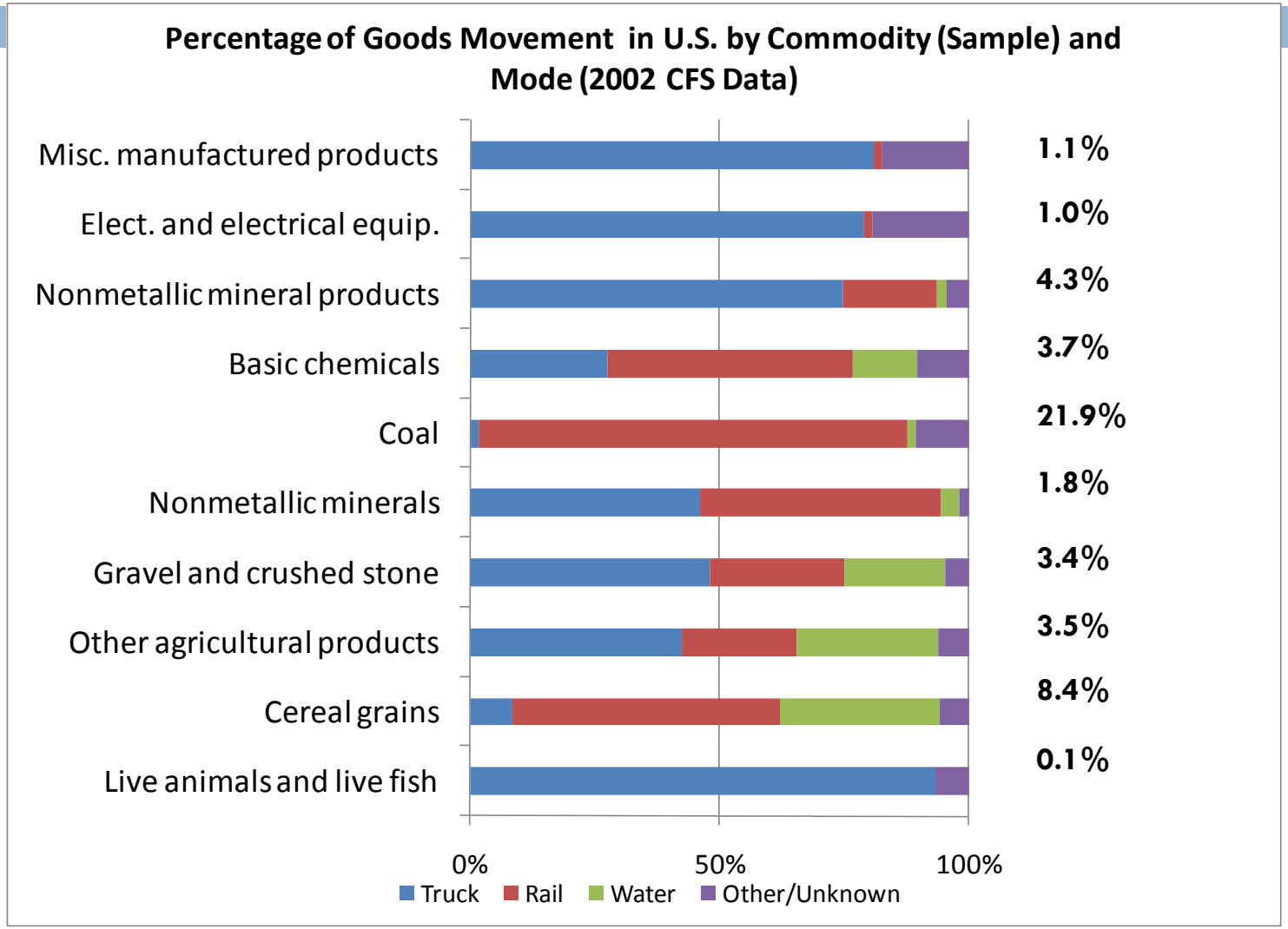
$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$

ΔE_{ij} = *energy savings due to modal shift from i to j*
W_{ik} = *work done by mode i for commodity k (ton-miles)*
$\boldsymbol{c_{ijk}}$ = *shipment* ***compatibility fraction*** *of i to j for k (cargo)*
$\boldsymbol{f_{ijk}}$ = *shipment* ***feasibility fraction*** *of i to j for k (infrastructure)*
$\boldsymbol{p_{ijk}}$ = *shipment* ***practicality fraction*** *of i to j for k (economic)*
E_i = *energy intensity factor for i (Btu/ton-mile)*
E_j = *energy intensity factor for j (Btu/ton-mile)*

Also need to account for intermodal transfer penalties.

J. Winebrake, Asilomar, 2009.

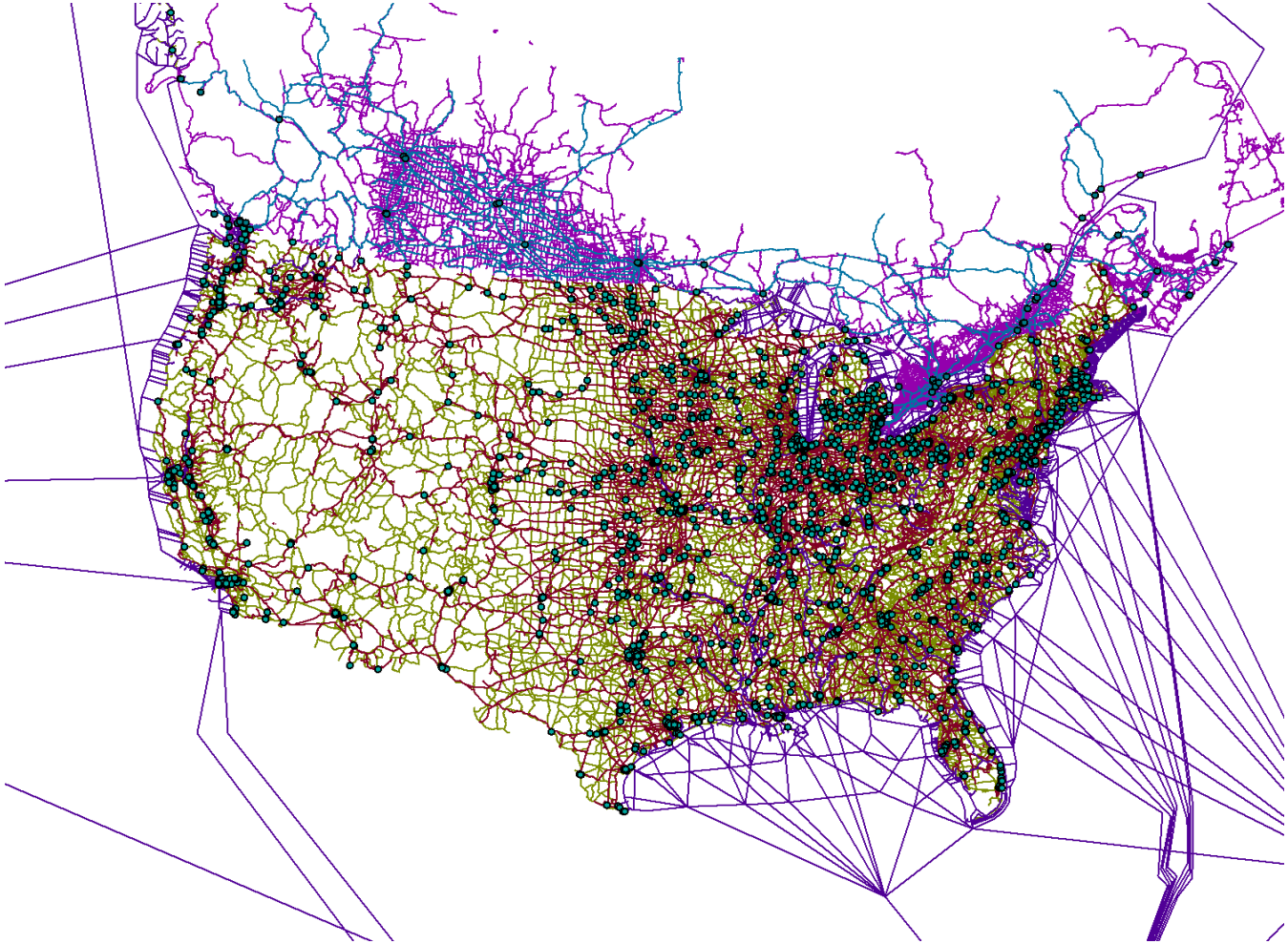
Insights into c_{ijk} – Cargo Characteristics



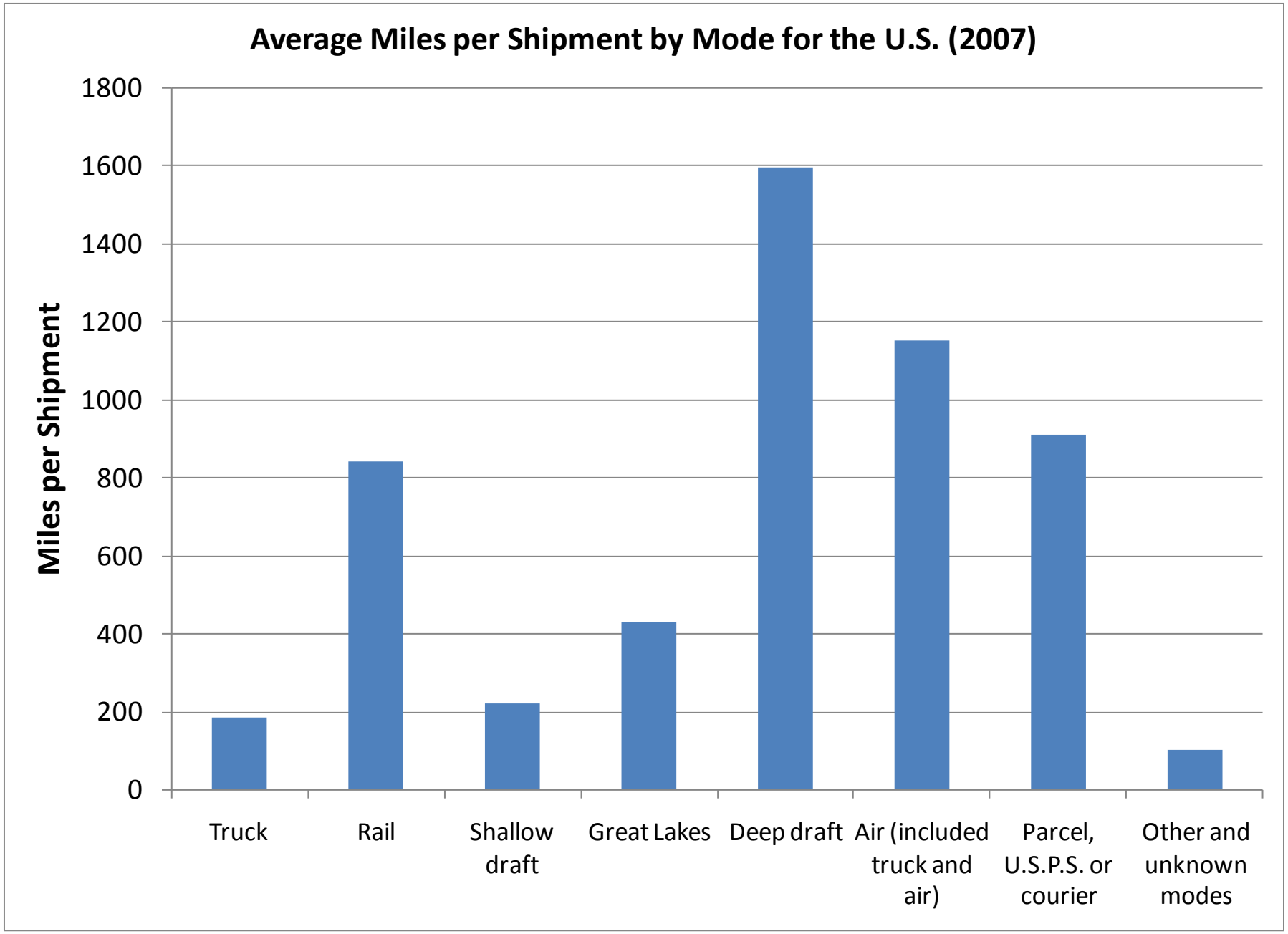
J. Winebrake, Asilomar, 2009.

Source: CFS 2002, Ton-Miles by Commodity and Mode

Insights into f_{ijk} – U.S. Intermodal Infrastructure



J. Winebrake, Asilomar, 2009.

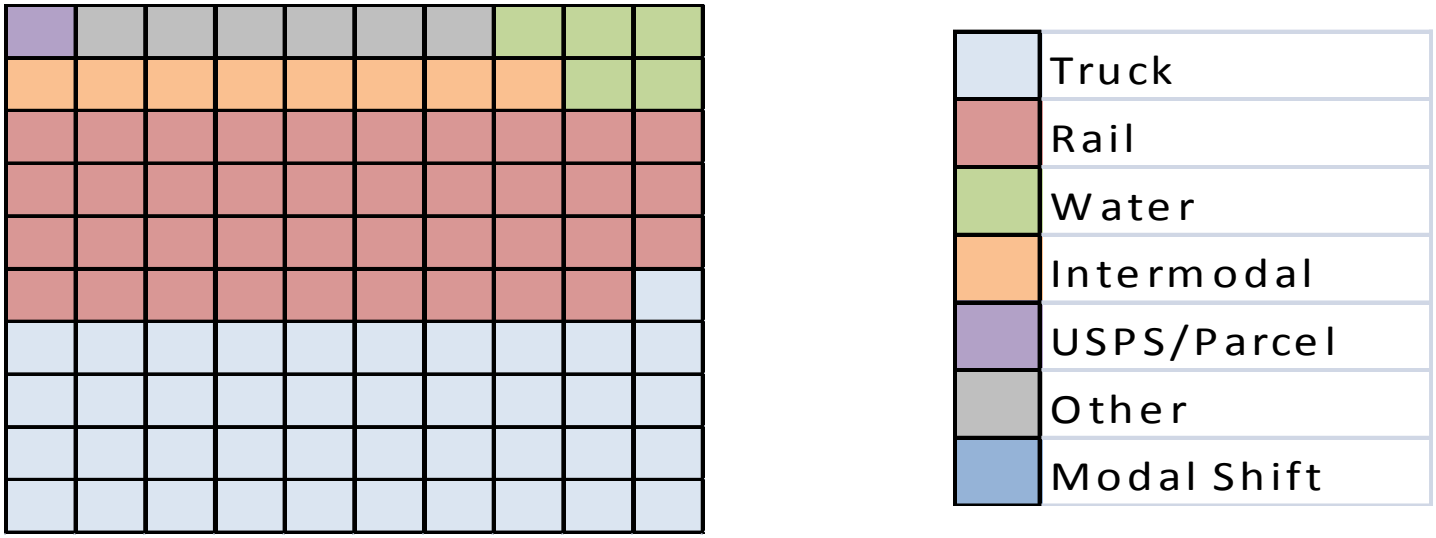


Source: CFS 2007.

J. Winebrake, Asilomar, 2009.

Estimating Mode Shifting Potential

$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$

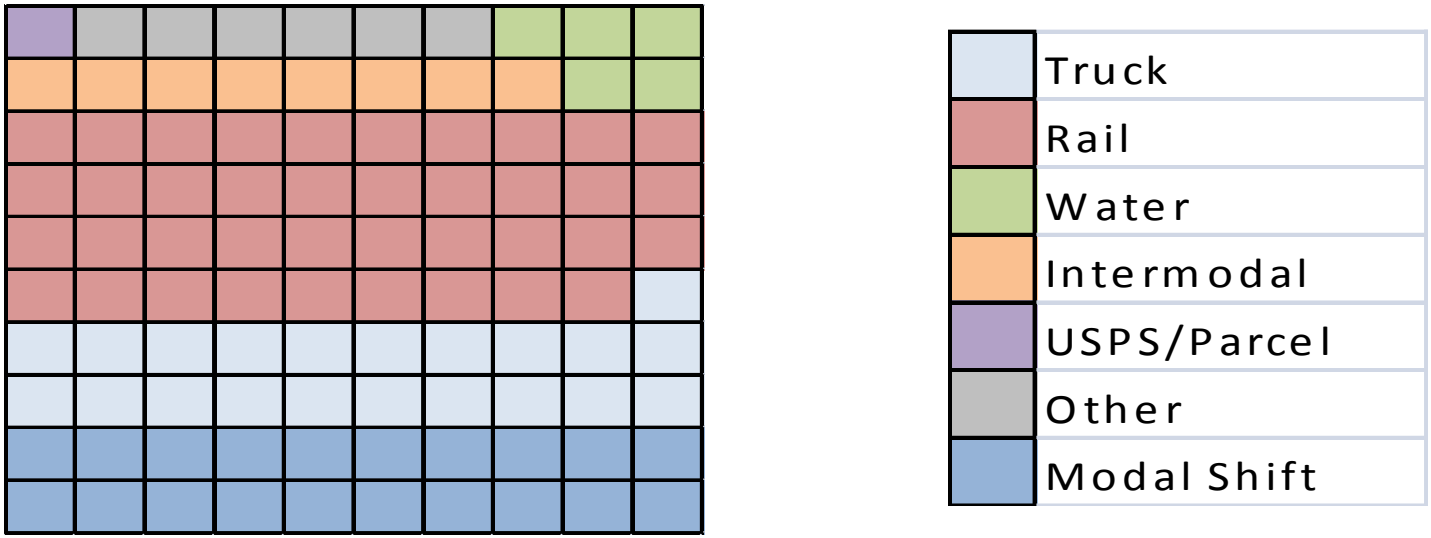


Consider total ton-miles as a gridded box, where each cell is equivalent to 1%.

J. Winebrake, Asilomar, 2009.

Estimating Mode Shifting Potential

$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$



Assume that about 50% of the cargo currently moved by truck is compatible with rail or ship due to physical properties, safety, loading logistics, etc. [c_{ijk} ~ 0.50]

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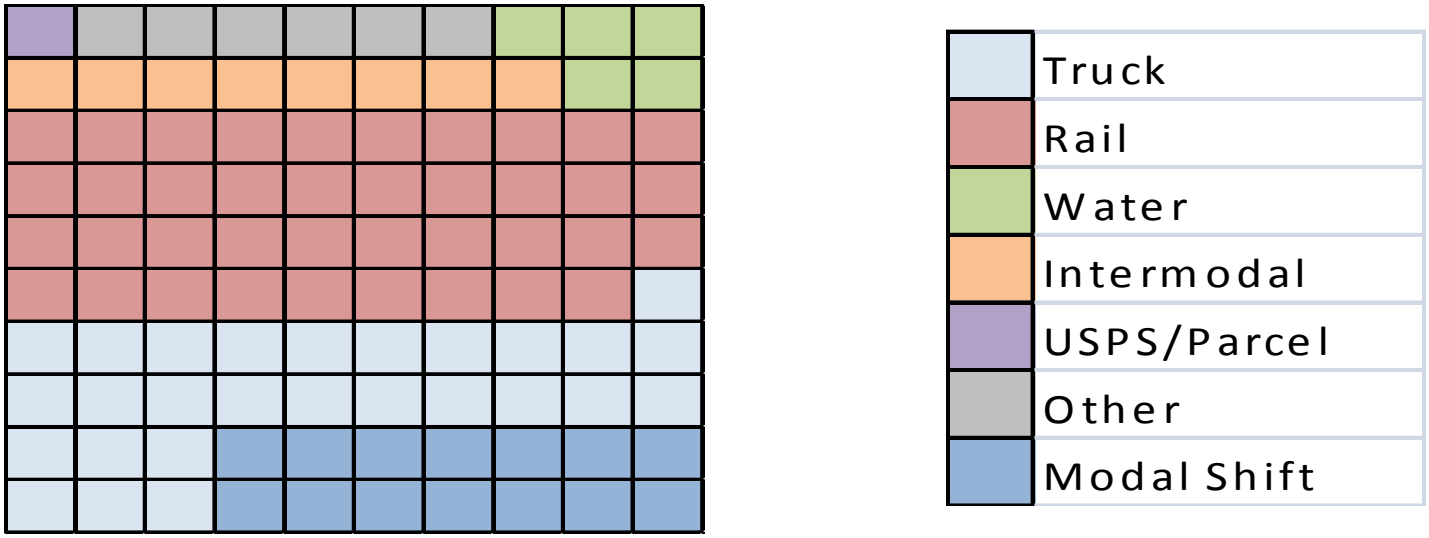
Estimating Mode Shifting Potential

$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$

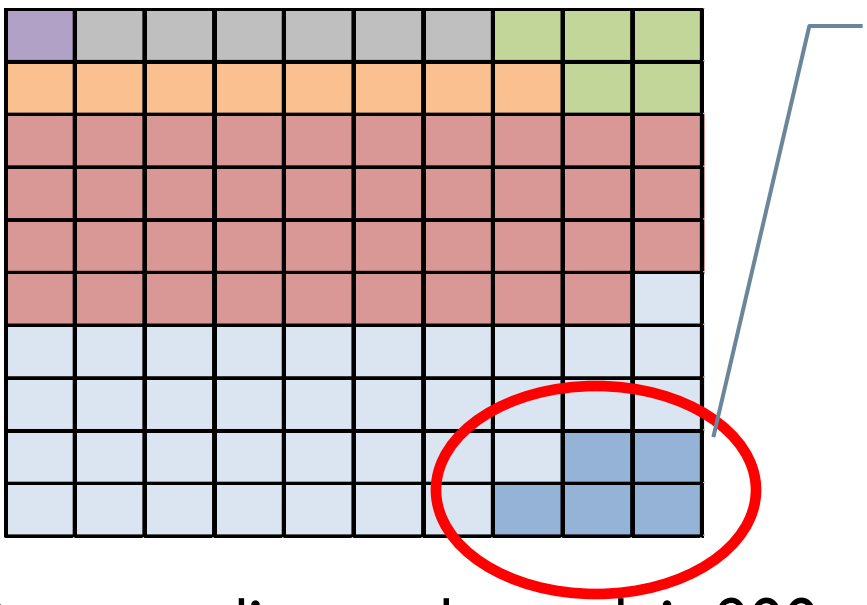


Assume that of the cargo that is compatible, infrastructure can only serve 70% of the ton-miles in the short term [f_{ijk} ~0.70]

J. Winebrake, Asilomar, 2009.

Estimating Mode Shifting Potential

$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$



Under these assumptions, there is potential to move ~ 5% of the total ton-miles (~12% of truck ton-miles) from truck to rail/ship. If truck is ~5 times more energy intense than rail/ship, then this implies ~8% reduction in energy consumption.

Average distance by truck is 200 miles. Assume that ~50% of the ton-miles shipped > 200 miles and 25% are > 500 miles. Assume economic possibility exists for mode shifting for 35% of total truck trips. [p_{ijk} ~ 0.35].

J. Winebrake, Asilomar, 2009.

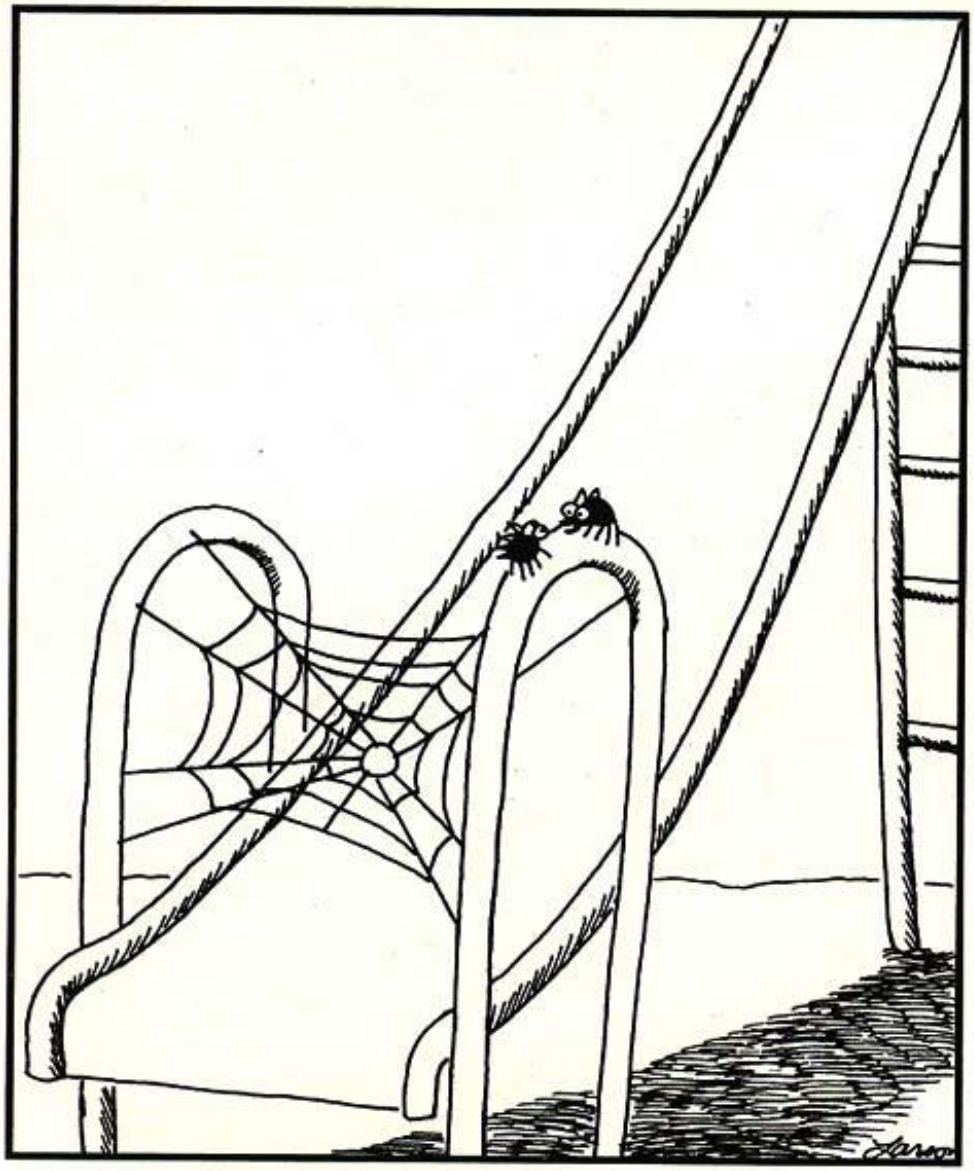
Policies for Promoting Efficiency

J. Winebrake, Asilomar, 2009.

Policy Options

Policy Options	I (Intermodalism)	F (Fuel)	T (Technology)	O (Operations)	L (Logistics)	D (Demand)
Efficiency standards	•		•		•	
Taxes	•	•	•	•	•	•
Subsidies	•	•	•			
Technology mandates			•			
Infrastructure investment	•				•	
R&D investment		•	•			
Alternative/LC fuels		•	•			
Size/weight restrictions	•			•	•	
Demand management						•

J. Winebrake, Asilomar, 2009.



"If we pull this off, we'll eat like kings."

J. Winebrake, Asilomar, 2009.